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(54) METHODS AND APPARATUS FOR DUAL CONFINEMENT AND ULTRA-HIGH PRESSURE IN AN ADJUSTABLE GAP PLASMA CHAMBER

VERFAHREN UND VORRICHTUNG FÜR DOPPELSCHUTZ UND ULTRAHOHEN DRUCK IN EINER EINSTELLBAREN GLASPLASMAKAMMER

PROCÉDÉS ET APPAREIL POUR LE DOUBLE CONFINEMENT ET L'ULTRA-HAUTE PRESSION DANS UNE CHAMBRE PLASMA À ÉCARTEMENT RÉGLABLE

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Description

BACKGROUND OF THE INVENTION

[0001] Advances in plasma processing have facilitated growth in the semiconductor industry. The semiconductor industry is a highly competitive market. The ability for a manufacturing company to be able to process substrates in different processing conditions may give the manufacturing company an edge over competitors. Thus, manufacturing companies have dedicated time and resources to identify methods and/or arrangements for improving substrate processing.

[0002] A typical processing system that may be employed to perform substrate processing may be a capacitively-coupled plasma (CCP) processing system. The plasma processing system may be built to enable processing in a range of process parameters. However, in recent years, the types of devices that may be processed have become more sophisticated and may require more precise process control. For example, devices being processed are becoming smaller with finer features and may require more precise control of plasma parameters, such as plasma density and uniformity across the substrate, for better yield. Pressure control of the wafer area in the etching chamber may be an example of a process parameter affecting plasma density and uniformity.

[0003] The manufacturing of semiconductor devices may require multi-step processes employing plasma within a plasma processing chamber. During plasma processing of semiconductor device(s), the plasma processing chamber may typically be maintained at a predefined pressure for each step of the process. The redefined pressure may be achieved through employing mechanical vacuum pump(s), turbo pump(s), confinement ring positioning and/or combinations thereof, as is well known by those skilled in the art.

[0004] Conventionally, a valve assembly may be employed to throttle the exhaust turbo pump(s) to attain pressure control for maintaining predefined pressure conditions in the plasma processing chamber. However, the pressure being controlled by the vat valve may result in a global change in the entire chamber without the capability of providing differential pressure control in different regions of the chamber.

[0005] In the prior art, the pressure in the plasma generating region of the plasma processing chamber (e.g., the region encapsulated by the two electrodes and surrounded by the confinement rings) may be controlled by adjusting the gaps between the confinement rings of a confinement ring assembly. Adjusting the gaps controls the flow rate of exhaust gas from the plasma generating region and pressure may be affected as a result. The overall gas flow conductance out of the plasma generating region may depend on several factors, including but not limited to, the number of confinement rings and the size of the gaps between the confinement rings. Thus, the operating windows for the pressure range may be limited by the chamber gap and/or the gaps of these confinement rings. Furthermore, the plasma cross section may be a fixed diameter for the aforementioned process due to the fix diameter of these confinement rings.

[0006] In the prior art, a plasma processing chamber configured with the capability to sustain a plurality of differentiated plasma volumes may be employed to address the aforementioned problem of plasma of fixed cross section. In an example, a wide-gap configuration may be employed to provide an increased plasma cross section with relatively low pressure. In another example, a narrow-gap configuration may be employed to provide the conventional plasma cross section but relatively higher pressure may be attained. However, active differentiated pressure control for the system is not provided. Document WO-A2-02/31859 discloses a parallel-plate plasma processing system wherein the upper electrode comprises a peripheral portion, which is stepped for controlling the plasma density.

[0007] Document JP 2004119448 discloses a plasma etching apparatus, wherein the interelectrode distance is changed to constantly control the pressure of the processing chamber and realize uniform plasma etching.

[0008] Document US-A1-0040931 discloses a parallel-plate plasma processing system comprising a focus ring arranged on the lower electrode and a shield ring mounted on the top electrode. Document US-A1-20080241420 discloses a plasma processing system including an upper electrode with a stepped peripheral extension, and a lower electrode with a cover ring. Document WO-A2-2008/082518 discloses a capacitively-coupled plasma chamber, wherein the plasma conditions can be quickly and accurately controlled by a confinement ring assembly, which enables pressure control and plasma confinement over the entire range of the interelectrode gap, and a by-pass ring.

[0009] In view of the need to process the substrate in multiple steps, each of which may involve a different pressure, improvement to the capability to provide differentiated pressure control over a wider range of pressure in plasma processing systems is highly desirable.

SUMMARY OF INVENTION

[0010] The invention relates, in an embodiment, to a plasma processing system having a plasma processing chamber configured for processing a substrate. The plasma processing system includes at least an upper electrode and a lower electrode for processing the substrate. The substrate is disposed on the lower electrode during plasma processing, where the upper electrode and the substrate forms a first gap. The plasma processing system also includes an upper electrode peripheral extension (UE-PE). The UE-PE is mechanically coupled to a periphery of the upper electrode, where the UE-PE is configured to be non-coplanar with the upper electrode. The plasma processing system further includes a cover ring. The cover ring is configured to concentrically surround the lower electrode, where the UE-PE and the cover ring forms a second gap.

[0011] The above summary relates to only one of the many embodiments of the invention disclosed herein and is not intended to limit the scope of the invention, which is set forth is the claims herein. These and other features of the present invention will be described in more detail below in the detailed description of the invention and in conjunction with the following figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

> Fig. 1 shows, in accordance with an embodiment of the present invention, a simplified schematic of a plasma processing system configured with an adjustable gap between an upper electrode assembly and a lower electrode assembly to yield a narrow gap configuration with a symmetric chamber for ultra-high pressure and/or low conductance regime.
>
> Fig. 2 shows, in accordance with an embodiment of the present invention, a simplified schematic of a plasma processing system configured with an adjustable gap between an upper electrode assembly and a lower electrode assembly to yield a wide gap configuration with an asymmetric chamber for low pressure and/or high conductance regime.

DETAILED DESCRIPTION OF EMBODIMENTS

[0013] The present invention will now be described in detail with reference to a few embodiments thereof as illustrated in the accompanying drawings. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent however, to one skilled in the art, that the present invention may be practiced without some or all of these specific details. In other instances, well known process steps and/or structures have not been described in detail in order to not unnecessarily obscure the present invention.

[0014] In accordance with embodiments of the invention, there are provided methods and apparatus for providing a wide range of pressure in the same plasma processing chamber. In some plasma processing systems, the chamber gap (i.e., the gap between the upper and lower electrode) is a recipe parameter and may vary from step to step. In these plasma processing systems, there may be provided a mechanism configured to move the lower electrode assembly to adjust the chamber gap. In other plasma processing systems, the upper electrode assembly may be moved. In the disclosure herein, the chamber is assumed to have a moving lower electrode. It should be understood, however, that embodiments of the invention herein apply equally well to chambers in which the upper electrode is movable (alternatively or additionally).

[0015] In one ore more embodiments, the upper electrode is grounded while the lower electrode is powered. In an implementation, the periphery of the upper electrode is provided with an annular, i.e., donut-shaped, ring that surrounds the upper electrode. The annular extension is referred herein as the upper electrode peripheral extension (UE-PE).

[0016] The gap bellow the UE-PE is to a quartz cover ring may be configured such that as the gap between the upper electrode and the lower electrode is sufficiently narrowed, there comes a point where the gap below the UE-PE is insufficiently large to sustain plasma below the UE-PE while the gap that under lies the upper electrode inside of the UE-PE still remain sufficiently large to sustain plasma. In this narrow-gap case, the gap below UE-PE may represent an area of very high flow restriction. In an embodiment, the height of the gap below UE-PE may be adjusted to control the pressure to attain ultra-high pressure and low conductance in the area of the gap that under lies the upper electrode inside of the UE-PE.

[0017] As the gap between the upper electrode and the lower electrode is gradually enlarged whereas the gap below the UE-PE is insufficiently large to sustain plasma while the gap that under lies the upper electrode inside of the UE-PE still remain sufficiently large to sustain plasma, lower pressure and higher conductance may be achieved for the narrow-gap configuration in an embodiment.

[0018] As the gap between the upper electrode and the lower electrode is further gradually enlarged, there comes a point where the gap below the UE-PE is sufficiently large to sustain plasma while the gap that under lies the upper electrode inside of the UE-PE is also sufficiently large to sustain plasma. In this wide-gap configuration, low pressure and high conductance may be achieved. The confinement rings may be employed to contain plasma and/or control pressure.

[0019] As may be appreciated from the foregoing, the effective RF coupling area of the powered lower electrode remains the same for both the narrow-gap configuration and the wide-gap configuration. However, in the wide-gap configuration, the effective RF coupling area of the grounded electrode is enlarged. Accordingly, the narrow-gap configuration may provide for a first area ratio of RF coupling while the wide-gap configuration may provide for a second area ratio of RF coupling, i.e., larger due to a larger effective RF ground coupling area.

[0020] In an embodiment, the difference in gaps (i.e., the gap between the upper electrode and lower electrode at the central region of the upper electrode and the gap below the UE-PE) may be accomplished by making the UE-PE non co-planar with the upper electrode. For example, the UE-PE may protrude below the upper electrode. The UE-PE moves together with the upper electrode in implementation wherein the upper electrode is movable.

[0021] In another embodiment, a lower electrode periphery extension (LE-PE) may be employed to be non-coplanar with the lower electrode. For example, the LE-PE may be raised above the electrode. In an example, the LE-PE may be quartz cover ring. The LE-PE moves together with the lower electrode in implementation wherein the lower electrode is movable.

[0022] The features and advantages of the present invention may be better understood with reference to the figures and discussions (with prior art mechanisms and embodiments of the invention contrasted) that follow.

[0023] Fig. 1 shows, in accordance with an embodiment of the present invention, a simplified schematic of a plasma processing system configured with an adjustable gap between an upper electrode assembly and a lower electrode assembly to yield a narrow gap configuration with a symmetric chamber for ultra-high pressure and/or low conductance regime. Plasma processing system 100 may be a single, double or triple frequency capacitively discharged system or may be an inductively coupled plasma system or a plasma system employing a different plasma generating and/or sustaining technology. In the example of Fig. 1, radio frequency may include, but are not limited to, 2, 27 and 60 MHz.

[0024] Referring to Fig. 1, plasma processing system 100 may be configured with an upper electrode assembly 102 and a lower electrode assembly 104, in an embodiment. The upper electrode assembly 102 and lower electrode assembly 104 may be separated from each other by a chamber gap 106. The upper electrode assembly 102 may include at least an upper electrode that may be grounded or powered by an RF power supply (not shown).

[0025] In the example of Fig. 1, upper electrode assembly 102 may be grounded in an embodiment. Further, upper electrode assembly 102 may be configured with an inner upper electrode component 102a and an outer upper electrode component 102b in an embodiment. Outer electrode component 102b may be an annular extension of inner upper electrode 102a in an embodiment. Herein, outer electrode component 102b may be referred to as an upper electrode peripheral extension (UE-PE).

[0026] As shown in Fig. 1, inner upper electrode component 102a and UE-PE 102b may be formed from different components as shown in Fig. 1. Alternatively, inner upper electrode 102a and UE-PE 102b may be formed as a monolithic unit in an embodiment. Further, inner upper electrode 102a and/or UE-PE 102b may be formed from a plurality of components in an embodiment.

[0027] Lower electrode assembly 104 may be configured with an electrostatic chuck (ESC) 110, an edge ring 112, an insulator ring 114, a focus ring 116, a quartz cover ring 118, confinement ring assembly 124, and/or a by-pass ring 120 in an embodiment. As shown in Fig. 1, by-pass ring 120 may be formed from aluminum. In an embodiment, by-pass ring 120 may be configured with a by-pass cavity 122 to allow gas to exhaust through by-pass cavity 122. As shown in Fig. 1, a vat valve 134 coupled to a turbo molecular pump (TMP) 136 may be employed to exhaust processed gas from plasma processing system 100. The features of the aforementioned components are well known by those skilled in the art and will not be discussed in detail to simplify the discussion.

[0028] In an embodiment, UE-PE 102b may be configured with a step, i.e., choke point 126. As a result of the step, the lower surface of UE-PE 102b may extend or protrude below the lower surface of inner upper electrode 102a. As shown in Fig. 1, the lower surface of UE-PE 102b and the top surface of quartz cover ring 118 may be separated by a second gap 128 in an embodiment. The size of gap 128 may be adjustable by moving upper electrode assembly 102 and/or lower electrode assembly in an embodiment.

[0029] In an embodiment, the choke point may be formed by making a non co-planar step. For example, the UF-PE may extend or protrude below the surface of the upper electrode. Alternatively or additionally, a lower electrode periphery extension (LE-PE) may be employed to be non-coplanar with the lower electrode. For example, the LE-PE may be raised above the electrode. In an example, the LE-PE may be quartz cover ring 118.

[0030] As shown in Fig. 1, plasma processing system 100 may be configured with two possible plasma sustaining regions: region 130a OR regions 130a plus 128 plus 130b. In an embodiment, region 130a may be capable of sustaining plasma whenever chamber gap 106 is sufficiently large to sustain plasma. Whereas, regions 130a plus 128 plus 130b may be capable of sustaining plasm whenever gap 128 in the choke region is sufficiently large to sustain plasma in an embodiment. This is depicted in Figure 2.

[0031] During plasma processing, processed gas (not shown) may be supplied into chamber gap 106. The processed gas being supplied into chamber gap 106 may be excited into a plasma state by RF power supplied to lower electrode assembly 104. Consider the situation wherein, for example, slower electrode assembly 104 may be moved to create a narrow-gap configuration wherein the size of gap 128 may be insufficient large (relative to the mean free path) to sustain plasma.

[0032] In the narrow-gap configuration of Fig. 1, plasma may be sustained in region 130a of chamber gap 106 in an embodiment. Gap 128 of choke region may be insufficiently large to sustain plasma. Therefore, region 130b may be incapable of sustaining plasma. In the narrow gap configuration confinement ring assembly 124 is pulled up to limit additional flow obstructions.

[0033] In an embodiment, the upper electrode and lower electrode may be sized such that in the narrow-gap configuration, a 1:1 area ratio may be achieved, making the chamber a symmetric chamber in the narrow-gap configuration.

[0034] In the narrow-gap configuration, differential pressure between region 130a and the rest of plasma processing system may be attained and controlled in an embodiment. In an example, the pressure in chamber gap 106 may be controlled by an active feedback loop. In an embodiment, the pressure in region 130a may be measures and gap 128, vat valve 134 and/or gas flow rate may be adjusted to control the pressure in region 130a.

[0035] Consider the situation wherein, for example, ultra-high pressure, e.g., in the hundreds of Pa range (in the Torr range), may be desired in region 130a during plasma processing of a substrate 108. Lower electrode assembly 104 may be moved to a reduced height to form a very narrow gap for gap 128. The choke region of gap 128 may represent an area of very high flow restriction choking the gas flow significantly. In an embodiment, the height of gap 128 is insufficiently large to sustain plasma in gap 128 and/or region 130b.

[0036] Through the aforementioned active pressure feedback loop, pressure in region 130a may be controlled by adjusting the height of gap 128. For example, the pressure in region 130a may be increased by further reducing the height of gap 128. In an embodiment gap 128 remains insufficiently large to sustain plasma in region 130b throughout the range of pressure controlled through adjusting gap 128.

[0037] Alternatively and/or additionally, the pressure in region 130a may be controlled by adjusting the flow of processed gas through region 130a in an embodiment In an example, the flow of processed gas may be increased to increase pressure in region 130a to increase pressure to attain ultra-high pressure in region 130a.

[0038] Alternatively and/or additionally, pressure control of region 130a may be achieved by adjusting vat valve 134 upstream of TMP 136 in an embodiment. In an example, vat valve 134 may be throttle closed to back pressure plasma chamber region to increase pressure to attain ultra-high pressure in region 130a.

[0039] Referring to Fig. 1, a confinement ring set 124 may not be employed in pressure control for ultra-high pressure regime because flow restriction is insignificant in comparison to the flow restriction from gap 128. In addition, confinement ring set 124 is parallel of by-pass ring 120, which has even higher conductance than the gaps between confinement ring set 124. For example, confinement ring set 124 may be configured in the collapsed state resting on shoulder 132 of by-pass ring 120 or may be pulled up into the wafer transport position as shown in Figure 1. Gas conductance through by-pass cavity 122 of by-pass ring 120 may render pressure control from confinement ring set 124 inconsequential.

[0040] Accordingly, region 130a may be able to attain ultra-high pressure, e.g., up to about 667 Pa (about 5 Torr), due to the high flow rate and/or the high flow restriction. Thus, a symmetric chamber with a narrow gap configuration may attain ultra-high pressure and/or low conductance independent of the rest of the processing chamber in an embodiment.

[0041] In the prior art, gap 128 may be employed to extinguish plasma in region 130b by narrowing the size of gap 128 to be insufficient large to sustain plasma. In contrast, gap 128 may be employed not only to extinguish plasma in region 130b, but gap 128 may be adjusted to control pressure in region 130b. Thus, gap 128 may be narrowed beyond the point to extinguish plasma for pressure control.

[0042] Consider another situation wherein, for example, low pressure and/or high conductance may be desired in region 130a during plasma processing for the configuration with a symmetric chamber and narrow gap. Fig. 1 is employed to illustrate the example of low pressure and/or high conductance regime with the symmetric chamber. For example, lower electrode assembly 104 may be moved such that gap 128 is sufficiently large to reduce flow restriction but still able to prevent plasma ignition in region 130b in an embodiment.

[0043] Referring to Fig. 1, plasma is sustained in region 130a. Gap 128 is sufficiently narrowed to extinguish plasma, and plasma is not sustained in region 130b. In an embodiment, gap 128 may be sufficiently large to increase gas conductance resulting in lower pressure in region 130a. In an embodiment, pressure control of region 130a may be attained by adjusting gap 128. The upper range for the seize of gap 128 may be limited to the size of gap 128 (relative to the mean free path) to sustain plasma in an embodiment.

[0044] Alternatively and/or additionally, the pressure in region 130a may be controlled by adjusting the flow of processed gas through region 130a in an embodiment. In an example, the flow of processed gas may be reduced to decrease pressure in region 130a.

[0045] Alternatively and/or additionally, pressure control of region 130a may be achieved by adjusting vat valve 134 upstream of TMP 136 in an embodiment. In an example, vat valve 134 may be throttle opened to reduce pressure in region 130a.

[0046] In the low pressure regime with the symmetric chamber, confinement ring set 124 may be employed to control pressure. Referring to Fig. 1, confinement ring set 124 may be lowered and pressure in region 130a may be controlled by adjusting the gaps between confinement ring set 124. Methods for controlling pressure employing confinement ring set is well known by those skilled in the art and is not discussed in detail to simplify discussion.

[0047] Accordingly, a lower pressure regime may be achieved with symmetric chamber configuration by adjusting gap 128 to increase conductance while preventing external region 130b from sustaining plasma. Pressure in region 130a may be controlled by adjusting gap 128, confinement ring set 124, gas flow rate, and/or vat valve 134.

[0048] Fig. 2 shows, in accordance with an embodiment of the present invention, a simplified schematic of a plasma processing system configured with an adjustable gap between an upper electrode assembly 102 and a lower electrode assembly 104 to yield a wide gap configuration with an asymmetric chamber for low pressure and/or high conductance regime. Fig. 2 is discussed in relation to Fig. 1 to facilitate understanding.

[0049] Consider the situation wherein, for example, low pressure, e.g., as low as about 0.67 Pa (about 5 milli-Torr), may be desired for processing of substrate 108 in plasma processing system 200, as shown in Fig. 2. The low pressure and/or high conductance may be attained by moving lower electrode assembly 104 in the direction of an arrow 240 to increase the height of gap 128 in an embodiment. The increase in height of gap 128 may result in higher conductance. In an embodiment, gap 128 is sufficiently large and plasma may be sustained in a region 230. Region 230 may extend from the center of the chamber out to the inner edge of confinement ring sent 124. As shown in Fig. 2. confinement ring set 124 may be employed to confine plasma within a specific region.

[0050] In the wide-gap configuration of Fig. 2, the area ratio of the grounded upper electrode to the powered lower electrode may be high, i.e., the ratio may be greater than 1:1, making the chamber asymmetric. In contrast to the symmetric configuration, plasma is sustained in region 230 for the asymmetric configuration as shown in Fig. 2 instead of plasma being only sustained in region 130a as shown in Fig. 1. For example, a high ratio of ground to powered RF electrode areas may result in high bias voltage and high ion energy at substrate 108 for the wide-gap configuration.

[0051] As shown in Fig. 2, gas may flow out of region 230 through by-pass cavity 122 of by-pass ring 120 contributing to the capability of attaining low pressure for the asymmetric configuration. Due to by-pass cavity 122 and the increased height of gap 128, the high pressure that may be attained in the asymmetric configuration may be limited.

[0052] In the low pressure asymmetric configuration, pressure in region 230 may be controlled by adjusting the gaps of confinement ring set 124, as shown in Fig. 2. Confinement ring set 124 may be lowered and pressure may be controlled by adjusting the gaps between confinement ring set 124.

[0053] Alternatively and/or additionally, the pressure in region 230 may be controlled by adjusting the flow of processed gas through region 130 in an embodiment In an example, the flow of processed gas may be reduced to decrease pressure in region 230.

[0054] Alternatively and/or additionally, pressure control of region 230 may be achieved by adjusting vat valve 134 upstream of TMP 136 in an embodiment. In an example, vat valve 134 may be throttle opened to reduce pressure in region 230.

[0055] Accordingly, a lower pressure regime with increased conductance may be achieved in a wide-gap configuration of gap128 with an asymmetric chamber. Pressure in region 230 may be controlled by adjusting gaps between the confinement ring set 124, gas flow rate, and/or vat valve 134.

[0056] As can be appreciated from the forgoing, embodiments of the invention permit differentiated pressure control to provide a wide range of pressure and/or conductance in a plasma processing system. The range of pressure that may be attained may be from about 0.67 Pa to about 667 Pa (from about 5 milli-Torr to about 5 Torr). In the ultra-higb pressure range, plasma processing in the gamma mode may be possible. Furthermore, the different gap configurations may allow for control of grounded upper electrode to powered lower electrode area ratio allowing control of wafer bias and ion energy as well as ion energy distribution. Thus, substrate requiring various recipes over a wide range of pressure and/or bias and ion energy or ion energy distribution may be performed using the same plasma processing chamber reducing cost and/or time delay that may incur in employing multiple plasma processing chambers.

[0057] While this invention has been described in terms of several embodiments, there are alterations, permutations, and equivalents, which fall within the scope of this invention. It should also be noted that there are many alternative ways of implementing the methods and apparatuses of the present invention. Furthermore, embodiments of the present invention may find utility in other applications. The abstract section is provided herein for convenience and, due to word count limitation, is accordingly written for reading convenience and should not be employed to limit the scope of the invention. It is therefore intended that the invention be interpreted as including all such alterations, permutations, and equivalents as fall within the scope of the present invention. The invention is defined by the claims.

Claims

1. A plasma processing system having a plasma processing chamber configured to process a substrate (108), comprising:

   an upper electrode assembly (102) and a lower electrode assembly (104) for processing said substrate (108), the upper electrode assembly (102) comprising an upper electrode (102a) and an upper electrode peripheral extension (102b), the lower electrode assembly (104) comprising a lower electrode (110) and a cover ring (118), said substrate (108) being disposed on said lower electrode (110) during plasma processing, wherein said upper electrode (102a) and said lower electrode are arranged to form a first gap (106), wherein said upper electrode (102a) is arranged such that, in use, it is grounded and wherein said lower electrode (110) is arranged such that, in use, it is powered;

   wherein said upper electrode peripheral extension (102b) is arranged to be mechanically coupled to a periphery of said upper electrode

(102a), wherein said upper electrode peripheral extension (102b) is configured to be non-coplanar with said upper electrode (102a), wherein said upper electrode peripheral extension (102b) is arranged such that, in use, it is grounded,

wherein said cover ring (118) is configured to concentrically surround said lower electrode (110), where said upper electrode peripheral extension and said cover ring are arranged to form a second gap (128),

wherein said second gap (128) is smaller than said first gap (106), the plasma processing system further comprising a mechanism configured to move one of said upper electrode assembly (102) and said lower electrode assembly (104) in a direction perpendicular to a planar surface of said lower electrode (110) so as to simultaneously adjust said second gap (128) and said first gap (106) and so as to permit differentiated pressure control to provide a wide range of pressure and/or gas conductance in the plasma processing system.

2. The plasma processing system of claim 1, wherein said upper electrode peripheral extension (102b) and said upper electrode (102a) are formed as a monolithic unit.

3. The plasma processing system of claim 1, wherein said upper electrode peripheral extension (102b) and said upper electrode (102a) are formed from a plurality of components.

4. The plasma processing system of claim 1 further comprising a by-pass ring assembly.

5. The plasma processing system of claim 1 further comprising a confinement ring assembly (124).

6. The plasma processing system of claim 1 wherein said cover ring (118) is at least partially covered with quartz.

7. The plasma processing system of claim 1 further comprising a by-pass ring (120) having a by-pass cavity (122) for evacuating at least a portion of exhaust gas produced by said processing.

8. A method for controlling pressure in a plasma processing chamber, said method comprising:

providing at least an upper electrode (102a) and a lower electrode (110) for processing a substrate (108), disposing said substrate (108) on said lower electrode (110) during plasma processing, forming a first gap (106) between said upper electrode (102a) and said lower electrode (110), grounding said upper electrode (102a) and powering said lower electrode (110);

providing an upper electrode peripheral extension (102b), mechanically coupling said upper electrode peripheral extension (102b) to a periphery of said upper electrode, configuring said upper electrode peripheral extension (102b) to be non-coplanar with said upper electrode, grounding said upper electrode peripheral extension ;

providing a cover ring (118) configured to concentrically surround said lower electrode (110), forming a second gap (128) between said upper electrode peripheral extension (102b) and said cover ring (118), wherein said second gap (128) is smaller than said first gap (106);

generating a plasma within said plasma processing chamber to process said substrate; and

simultaneously adjusting said second gap and said first gap to permit differentiated pressure control to provide a wide range of pressure and/or gas conductance in the plasma processing system.

9. The method of claim 8, wherein said adjusting further include moving one of said upper electrode (102a) and said lower electrode (110) in a direction perpendicular to a planar surface of said lower electrode to change the height of said second gap (128), or
wherein said upper electrode peripheral extension (102b) and said upper electrode (102a) are formed as a monolithic unit, or
wherein said upper electrode peripheral extension (102b) and said upper electrode are formed from a plurality of components.

10. The method of claim 8 wherein said plasma processing chamber further includes a set of confinement rings, said method including:

deploying said set of confinement rings to regulate a process pressure when a first gap (106) exists between said upper electrode (102a) and said lower electrode (110); and

completely stowing said set of confinement rings when a second gap (128) exists between said upper electrode and said lower electrode due to said simultaneously adjusting, wherein said first gap is larger than said second gap.

11. The method of claim 8 wherein said cover ring (118) is at least partially covered with quartz.

12. A method for changing an area ratio of the upper electrode to the lower electrode in a plasma processing chamber, said method comprising:

providing at least an upper electrode (102a) and a lower electrode (110) for processing a substrate (108), disposing said substrate (108) on said lower electrode (110) during plasma processing, forming a first gap (106) between said upper electrode (102a) and said lower electrode (110), grounding said upper electrode (102a) and powering said lower electrode (110);
providing an upper electrode peripheral extension (102b), mechanically coupling said upper electrode peripheral extension to a periphery of said upper electrode, configuring said upper electrode peripheral extension to be non-coplanar with said upper electrode, grounding said upper electrode peripheral extension (102b);
providing a cover ring (118) configured to concentrically surround said lower electrode, forming a second gap (128) between said upper electrode peripheral extension (102b) and said cover ring (118), wherein said second gap (128) is smaller than said first gap (106);
generating a plasma within said plasma processing chamber to process said substrate; and
simultaneously adjusting said second gap and said first gap to change said area ratio of the upper electrode (102a) to the lower electrode (110) within said plasma processing chamber, said adjusting including moving one of said upper electrode and said lower electrode in a direction perpendicular to a planar surface of said lower electrode.

13. The method of claim 12 wherein only said upper electrode (102a) of said upper electrode (102a) and said lower electrode (110) is adjustable, or
wherein only said lower electrode (110) of said upper electrode (102a) and said lower electrode (110) is adjustable, or
wherein said adjusting results in at least a first area ratio and a second area ratio, said first area ratio representing 1:1 and thereby emulating a symmetric plasma processing chamber, said second area ratio is other than 1:1 and thereby emulating a non-symmetric plasma processing chamber.

Patentansprüche

1. Plasmabearbeitungssystem mit einer Plasmabearbeitungskammer, die dazu ausgestaltet ist, ein Substrat (108) zu bearbeiten, umfassend:

eine obere Elektrodenbaugruppe (102) und eine untere Elektrodenbaugruppe (104) zum Bearbeiten des Substrats (108), wobei die obere Elektrodenbaugruppe (102) eine obere Elektrode (102a) und eine Umfangserweiterung der oberen Elektrode (102b) umfasst, wobei die untere Elektrodenbaugruppe (104) eine untere Elektrode (110) und einen Abdeckring (118) umfasst, wobei das Substrat (108) während der Plasmabearbeitung auf der unteren Elektrode (110) angeordnet ist, wobei die obere Elektrode (102a) und die untere Elektrode derart angeordnet sind, dass sie einen ersten Spalt (106) bilden, wobei die obere Elektrode (102a) derart angeordnet ist, dass sie während des Betriebs geerdet ist und wobei die untere Elektrode (110) derart angeordnet ist, dass sie während des Betriebs mit Energie versorgt wird;
wobei die Umfangserweiterung der oberen Elektrode (102b) derart angeordnet ist, dass sie mechanisch mit einem Umfang der oberen Elektrode (102a) verbunden ist, wobei die Umfangserweiterung der oberen Elektrode (102b) derart ausgestaltet ist, dass sie nicht koplanar mit der oberen Elektrode (102a) ist, wobei die Umfangserweiterung der oberen Elektrode (102b) derart angeordnet ist, dass sie während des Betriebs geerdet ist,
wobei der Abdeckring (118) derart ausgestaltet ist, dass er die untere Elektrode (110) konzentrisch umgibt, wobei die Umfangserweiterung der oberen Elektrode und der Abdeckring derart angeordnet sind, dass sie einen zweiten Spalt (128) bilden,
wobei der zweite Spalt (128) kleiner als der erste Spalt (106) ist, wobei das Plasmabearbeitungssystem ferner einen Mechanismus umfasst, der dazu ausgestaltet ist, eine von der oberen Elektrodenbaugruppe (102) und der unteren Elektrodenbaugruppe (104) in einer Richtung zu bewegen, die senkrecht zu einer ebenen Oberfläche der unteren Elektrode (110) ist, um gleichzeitig den zweiten Spalt (128) und den ersten Spalt (106) einzustellen und um eine differenzierte Drucksteuerung zu ermöglichen, um einen breiten Bereich an Druck und/oder Gasleitfähigkeit in dem Plasmabearbeitungssystem bereitzustellen.

2. Plasmabearbeitungssystem nach Anspruch 1, wobei die Umfangserweiterung der oberen Elektrode (102b) und die obere Elektrode (102a) als eine monolithische Einheit ausgebildet sind.

3. Plasmabearbeitungssystem nach Anspruch 1, wobei die Umfangserweiterung der oberen Elektrode (102b) und die obere Elektrode (102a) aus einer Vielzahl von Komponenten gebildet sind.

4. Plasmabearbeitungssystem nach Anspruch 1, ferner umfassend eine Umgehungsringbaugruppe.

5. Plasmabearbeitungssystem nach Anspruch 1, ferner umfassend eine Einschlussringbaugruppe (124).

6. Plasmabearbeitungssystem nach Anspruch 1, wobei der Abdeckring (118) wenigstens teilweise mit Quarz bedeckt ist.

7. Plasmabearbeitungssystem nach Anspruch 1, ferner umfassend einen Umgehungsring (120), der einen Umgehungshohlraum (122) aufweist, um wenigstens einen Teil des durch die Bearbeitung erzeugten Abgases auszuleiten.

8. Verfahren zum Steuern des Drucks in einer Plasmabearbeitungskammer, wobei das Verfahren Folgendes umfasst:

> Bereitstellen von wenigstens einer oberen Elektrode (102a) und einer unteren Elektrode (110) zum Bearbeiten eines Substrats (108), Anordnen des Substrats (108) auf der unteren Elektrode (110) während der Plasmabearbeitung, Bilden eines ersten Spalts (106) zwischen der oberen Elektrode (102a) und der unteren Elektrode (110), Erden der oberen Elektrode (102a) und Versorgen der unteren Elektrode (110) mit Energie;
> Bereitstellen einer Umfangserweiterung der oberen Elektrode (102b), mechanisches Verbinden der Umfangserweiterung der oberen Elektrode (102b) mit einem Umfang der oberen Elektrode, Gestalten der Umfangserweiterung der oberen Elektrode (102b), so dass diese nicht koplanar mit der oberen Elektrode ist, Erden der Umfangserweiterung der oberen Elektrode;
> Bereitstellen eines Abdeckrings (118), der derart ausgestaltet ist, dass er die untere Elektrode (110) konzentrisch umgibt, Bilden eines zweiten Spalts (128) zwischen der Umfangserweiterung der oberen Elektrode (102b) und dem Abdeckring (118), wobei der zweite Spalt (128) kleiner als der erste Spalt (106) ist;
> Erzeugen eines Plasmas im Inneren der Plasmabearbeitungskammer, um das Substrat zu bearbeiten; und
> gleichzeitiges Einstellen des zweiten Spalts und des ersten Spalts, um eine differenzierte Drucksteuerung zu ermöglichen, um einen breiten Bereich an Druck und/oder Gasleitfähigkeit in dem Plasmabearbeitungssystem bereitzustellen.

9. Verfahren nach Anspruch 8, wobei das Einstellen ferner das Bewegen von einer aus der oberen Elektrode (102a) und der unteren Elektrode (110) in einer Richtung beinhaltet, die senkrecht zu einer ebenen Oberfläche der unteren Elektrode ist, um die Höhe des zweiten Spalts (128) zu verändern, oder wobei die Umfangserweiterung der oberen Elektrode (102b) und die obere Elektrode (102a) als monolithische Einheit ausgebildet sind oder wobei die Umfangserweiterung der oberen Elektrode (102b) und die obere Elektrode aus einer Vielzahl von Komponenten gebildet sind.

10. Verfahren nach Anspruch 8, wobei die Plasmabearbeitungskammer ferner einen Satz von Einschlussringen umfasst, wobei das Verfahren Folgendes beinhaltet:

> Ausfahren des Satzes von Einschlussringen, um einen Prozessdruck zu steuern, wenn ein erster Spalt (106) zwischen der oberen Elektrode (102a) und der unteren Elektrode (110) existiert; und
> vollständiges Verstauen des Satzes von Einschlussringen, wenn aufgrund der gleichzeitigen Einstellung ein zweiter Spalt (128) zwischen der oberen Elektrode und der unteren Elektrode existiert, wobei der erste Spalt größer als der zweite Spalt ist.

11. Verfahren nach Anspruch 8, wobei der Abdeckring (118) wenigstens teilweise mit Quarz bedeckt ist.

12. Verfahren zum Verändern eines Flächenverhältnisses zwischen der oberen Elektrode und der unteren Elektrode in einer Plasmabearbeitungskammer, wobei das Verfahren Folgendes umfasst:

> Bereitstellen von wenigstens einer oberen Elektrode (102a) und einer unteren Elektrode (110) zum Bearbeiten eines Substrats (108), Anordnen des Substrats (108) auf der unteren Elektrode (110) während der Plasmabearbeitung, Bilden eines ersten Spalts (106) zwischen der oberen Elektrode (102a) und der unteren Elektrode (110), Erden der oberen Elektrode (102a) und Versorgen der unteren Elektrode (110) mit Energie;
> Bereitstellen einer Umfangserweiterung der oberen Elektrode (102b), mechanisches Verbinden der Umfangserweiterung der oberen Elektrode mit einem Umfang der oberen Elektrode, Ausgestalten der Umfangserweiterung der oberen Elektrode, so dass diese nicht koplanar mit der oberen Elektrode ist, Erden der Umfangserweiterung der oberen Elektrode (102b);
> Bereitstellen eines Abdeckrings (118), der derart ausgestaltet ist, dass er die untere Elektrode konzentrisch umgibt, Bilden eines zweiten Spalts (128) zwischen der Umfangserweiterung der oberen Elektrode (102b) und dem Abdeckring (118), wobei der zweite Spalt (128) kleiner als der erste Spalt (106) ist;
> Erzeugen eines Plasmas im Inneren der Plas-

mabearbeitungskammer, um das Substrat zu bearbeiten; und

gleichzeitiges Einstellen des zweiten Spalts und des ersten Spalts, um das Flächenverhältnis der oberen Elektrode (102a) zur unteren Elektrode (110) im Inneren der Plasmabearbeitungskammer zu verändern, wobei das Einstellen das Bewegen von einer aus der oberen Elektrode und der unteren Elektrode in einer Richtung beinhaltet, die senkrecht zu einer ebenen Oberfläche der unteren Elektrode ist.

13. Verfahren nach Anspruch 12, wobei nur die obere Elektrode (102a) aus der oberen Elektrode (102a) und der unteren Elektrode (110) einstellbar ist, oder wobei nur die untere Elektrode (110) aus der oberen Elektrode (102a) und der unteren Elektrode (110) einstellbar ist, oder

wobei die Einstellung in wenigstens einem ersten Flächenverhältnis und einem zweiten Flächenverhältnis resultiert, wobei das erste Flächenverhältnis 1:1 ist und dadurch eine symmetrische Plasmabearbeitungskammer nachgebildet wird, wobei das zweite Flächenverhältnis anders als 1:1 ist und dadurch eine nicht symmetrische Plasmabearbeitungskammer nachgebildet wird.

Revendications

1. Système de traitement par plasma possédant une chambre de traitement par plasma configurée pour traiter un substrat (108) et comprenant :

un assemblage d’électrode supérieure (102) et un assemblage d’électrode inférieure (104) pour traiter ledit substrat (108), l’assemblage d’électrode supérieure (102) comprenant une électrode supérieure (102a) et une extension périphérique d’électrode supérieure (102b), l’assemblage d’électrode inférieure (104) comprenant une électrode inférieure (110) et une bague de couverture (118), ledit substrat (108) étant disposé sur ladite électrode inférieure (110) pendant le traitement par plasma, ladite électrode supérieure (102a) et ladite électrode inférieure étant disposées de façon à former un premier interstice (106), ladite électrode supérieure (102a) étant disposée de façon à être mise à la masse en service et ladite électrode inférieure (110) étant disposée de façon à être alimentée en énergie en service ;

dans lequel ladite extension périphérique d’électrode supérieure (102b) est arrangée de façon à être couplée mécaniquement à une périphérie de ladite électrode supérieure (102a), ladite extension périphérique d’électrode supérieure (102b) étant configurée pour être non coplanaire avec ladite électrode supérieure (102a), ladite extension périphérique d’électrode supérieure (102b) étant disposée de façon à être mise à la masse en service,

dans lequel ladite bague de couverture (118) est configurée pour entourer de façon concentrique ladite électrode inférieure (110), ladite extension périphérique d’électrode supérieure et ladite bague de couverture étant disposées pour former un deuxième interstice (128),

dans lequel ledit deuxième interstice (128) est plus petit que ledit premier interstice (106),

le système de traitement par plasma comprenant en outre un mécanisme configuré pour déplacer soit ledit assemblage d’électrode supérieure (102), soit ledit assemblage d’électrode inférieure (104) dans une direction perpendiculaire à une surface plane de ladite électrode inférieure (110) afin d’ajuster simultanément ledit deuxième interstice (128) et ledit premier interstice (106) et afin de permettre un contrôle de la pression différencié pour offrir une large plage de pression et/ou de conductance du gaz dans le système de traitement par plasma.

2. Système de traitement par plasma selon la revendication 1, dans lequel ladite extension périphérique d’électrode supérieure (102b) et ladite électrode supérieure (102a) sont construites comme une unité monolithique.

3. Système de traitement par plasma selon la revendication 1, dans lequel ladite extension périphérique d’électrode supérieure (102b) et ladite électrode supérieure (102a) sont formées de plusieurs composants.

4. Système de traitement par plasma selon la revendication 1, comprenant en outre un assemblage de bague de dérivation.

5. Système de traitement par plasma selon la revendication 1, comprenant en outre un assemblage de bagues de confinement (124).

6. Système de traitement par plasma selon la revendication 1, dans lequel ladite bague de couverture (118) est au moins en partie recouverte de quartz.

7. Système de traitement par plasma selon la revendication 1, comprenant en outre une bague de dérivation (120) possédant une cavité de dérivation (122) pour évacuer au moins une partie du gaz d’échappement produit par ledit traitement.

8. Procédé pour contrôler la pression dans une chambre de traitement par plasma, lequel procédé comprend :

la fourniture d'au moins une électrode supérieure (102a) et une électrode inférieure (110) pour traiter un substrat (108), la disposition dudit substrat (108) sur ladite électrode inférieure (110) pendant le traitement par plasma, la formation d'un premier interstice (106) entre ladite électrode supérieure (102a) et ladite électrode inférieure (110), la mise à la masse de ladite électrode supérieure (102a) et l'alimentation en énergie de ladite électrode inférieure (110) ;
la fourniture d'une extension périphérique d'électrode supérieure (102b), le couplage mécanique de ladite extension périphérique d'électrode supérieure (102b) avec une périphérie de ladite électrode supérieure, la configuration de ladite extension périphérique d'électrode supérieure (102b) pour qu'elle soit non coplanaire de ladite électrode supérieure, la mise à la masse de ladite extension périphérique d'électrode supérieure ;
la fourniture d'une bague de couverture (118) configurée pour entourer de façon concentrique ladite électrode inférieure (110), la formation d'un deuxième interstice (128) entre ladite extension périphérique d'électrode supérieure (102b) et ladite bague de couverture (118), ledit deuxième interstice (128) étant plus petit que ledit premier interstice (106) ;
la génération d'un plasma dans ladite chambre de traitement par plasma pour traiter ledit substrat ;
et
l'ajustement simultané dudit deuxième interstice et dudit premier interstice pour permettre un contrôle différencié de la pression afin d'offrir une large plage de pression et/ou de conductance du gaz dans le système de traitement par plasma.

9. Procédé selon la revendication 8, dans lequel ledit ajustement comprend en outre le déplacement soit de ladite électrode supérieure (102a), soit de ladite électrode inférieure (110) dans une direction perpendiculaire à une surface plane de ladite électrode inférieure afin de changer la hauteur dudit deuxième interstice (128), ou
dans lequel ladite extension périphérique d'électrode supérieure (102b) et ladite électrode supérieure (102a) sont construites comme une unité monolithique, ou
dans lequel ladite extension périphérique d'électrode supérieure (102b) et ladite électrode supérieure sont formées de plusieurs composants.

10. Procédé selon la revendication 8, dans lequel ladite chambre de traitement par plasma comprend en outre un ensemble de bagues de confinement, ledit procédé comprenant :

le déploiement dudit ensemble de bagues de confinement afin de réguler une pression de process quand il existe un premier interstice (106) entre ladite électrode supérieure (102a) et ladite électrode inférieure (110) ; et
l'escamotage complet dudit ensemble de bagues de confinement quand il existe un deuxième interstice (128) entre ladite électrode supérieure et ladite électrode inférieure en raison dudit ajustement simultané, ledit premier interstice étant plus grand que ledit deuxième interstice.

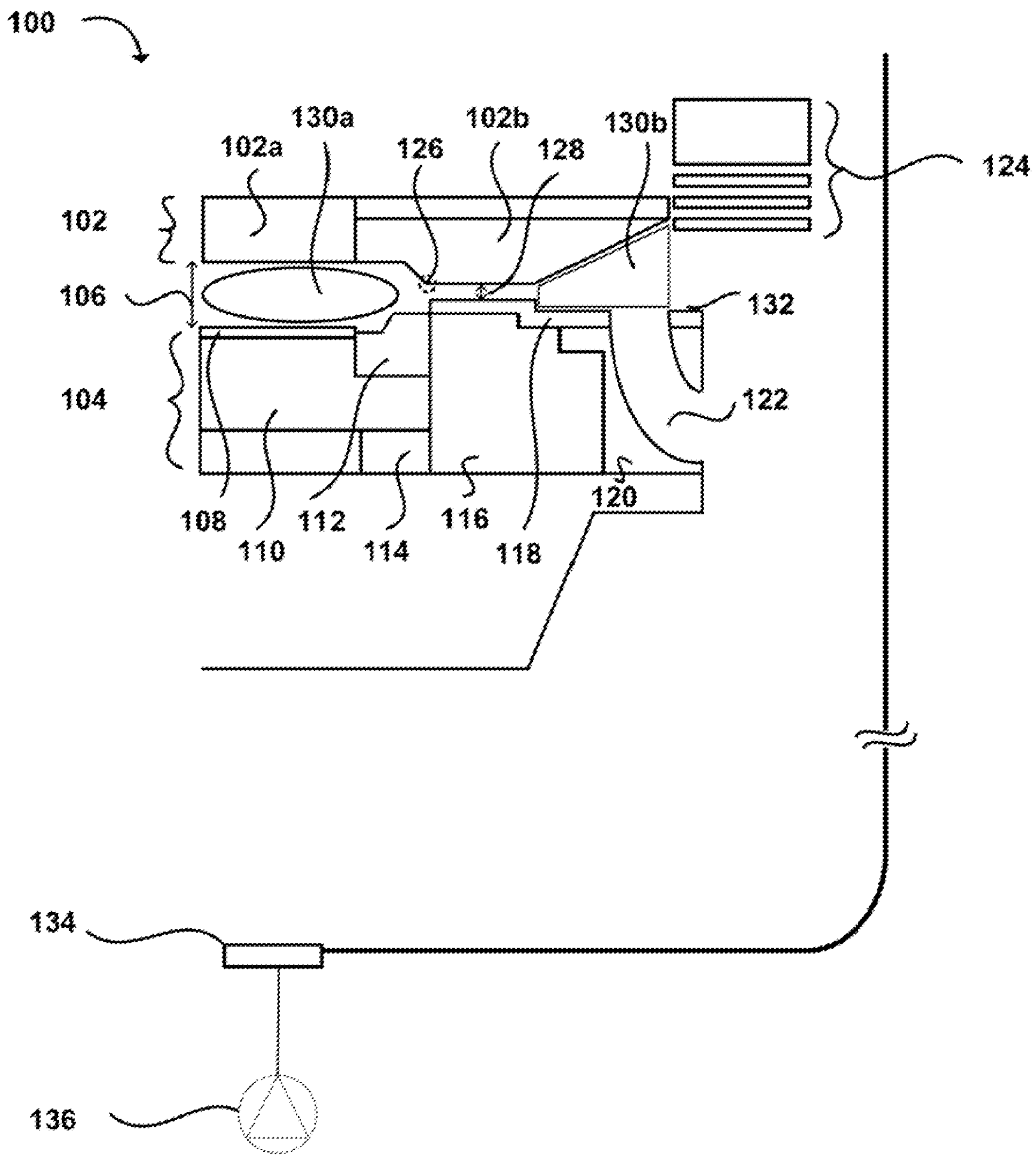
11. Procédé selon la revendication 8, dans lequel ladite bague de couverture (118) est au moins partiellement recouverte de quartz.

12. Procédé pour changer un rapport de section entre l'électrode supérieure et l'électrode inférieure dans une chambre de traitement par plasma, lequel procédé comprend :

la fourniture d'au moins une électrode supérieure (102a) et d'une électrode inférieure (110) pour traiter un substrat (108), la disposition dudit substrat (108) sur ladite électrode inférieure (110) pendant le traitement par plasma, la formation d'un premier interstice (106) entre ladite électrode supérieure (102a) et ladite électrode inférieure (110), la mise à la masse de ladite électrode supérieure (102a) et l'alimentation en énergie de ladite électrode inférieure (110) ;
la fourniture d'une extension périphérique d'électrode supérieure (102b), le couplage mécanique de ladite extension périphérique d'électrode supérieure avec une périphérie de ladite électrode supérieure, la configuration de ladite extension périphérique d'électrode supérieure pour qu'elle soit non coplanaire de ladite électrode supérieure, la mise à la masse de ladite extension périphérique d'électrode supérieure (102b) ;
la fourniture d'une bague de couverture (118) configurée pour entourer de façon concentrique ladite électrode inférieure, la formation d'un deuxième interstice (128) entre ladite extension périphérique d'électrode supérieure (102b) et ladite bague de couverture (118), ledit deuxième interstice (128) étant plus petit que ledit premier interstice (106) ;
la génération d'un plasma dans ladite chambre de traitement par plasma pour traiter ledit substrat ;
et
l'ajustement simultané dudit deuxième interstice et dudit premier interstice pour changer ledit rapport de section entre l'électrode supérieure (102a) et l'électrode inférieure (110) dans ladite chambre de traitement par plasma, ledit ajuste-

ment comprenant le déplacement soit de ladite électrode supérieure, soit de ladite électrode inférieure dans une direction perpendiculaire à une surface plane de ladite électrode inférieure.

13. Procédé selon la revendication 12, dans lequel seule ladite électrode supérieure (102a) parmi ladite électrode supérieure (102a) et ladite électrode inférieure (110) est ajustable, ou
dans lequel seule ladite électrode inférieure (110) parmi ladite électrode supérieure (102a) et ladite électrode inférieure (110) est ajustable, ou
dans lequel ledit ajustement donne au moins un premier rapport de section et un deuxième rapport de section, ledit premier rapport de section étant de 1:1 et émulant ainsi une chambre de traitement par plasma symétrique, ledit deuxième rapport de section étant différent de 1:1 et émulant ainsi une chambre de traitement par plasma non symétrique.


100
102a
130a
126
102b
128
130b
124
102
106
132
104
122
108
110
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114
116
120
118
134
136

Fig. 1

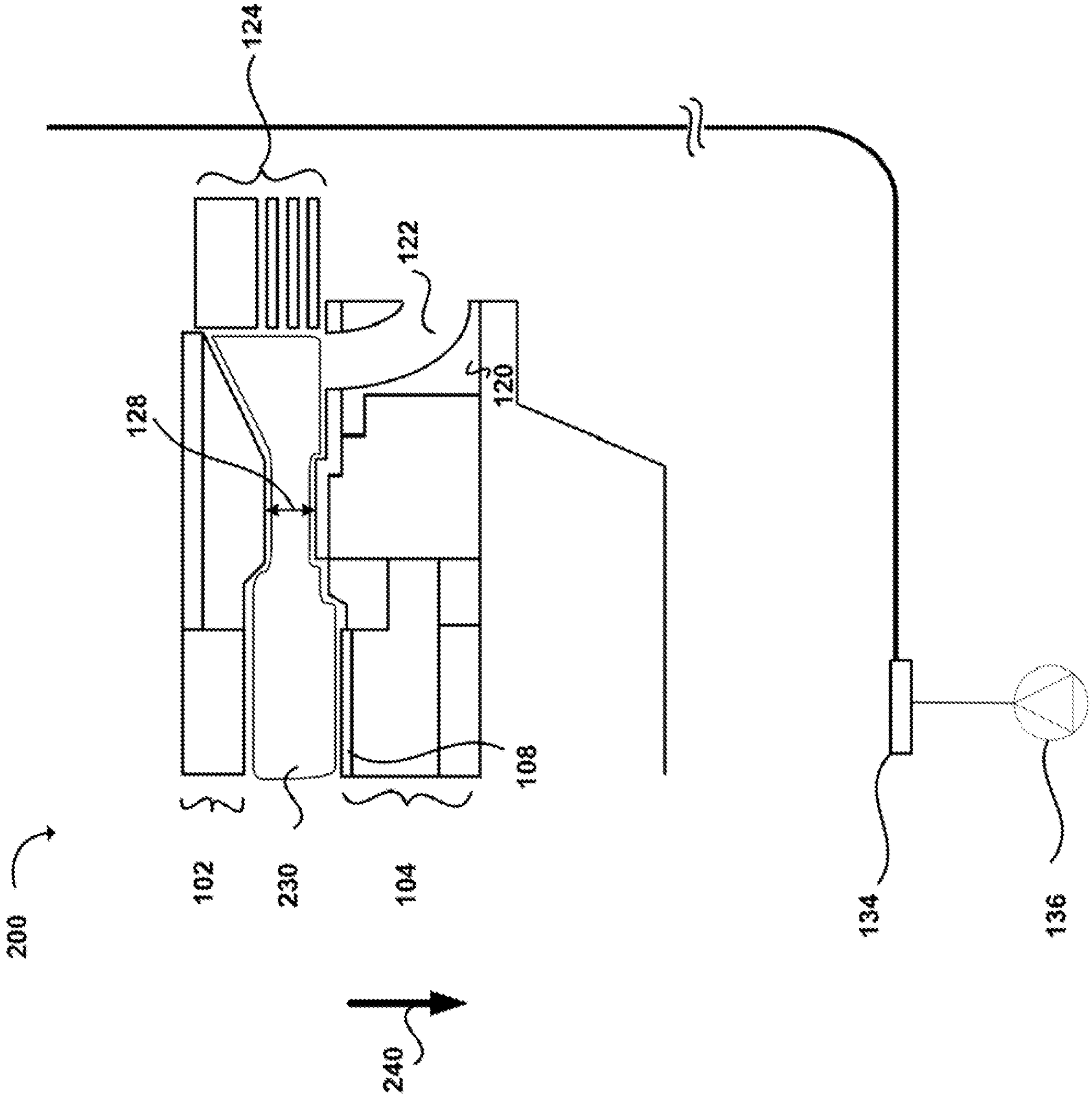

Fig. 2

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- WO 0231859 A2 **[0006]**
- JP 2004119448 B **[0007]**
- US 0040931 A1 **[0008]**
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